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ELECTRIC CARS IN SLOVENIA

ELEKTRIČNI AVTOMOBILI V SLOVENIJI

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Abstract

This article deals with electric vehicles in Slovenia. The introduction of electric cars is necessary in order to achieve the objectives of the European Union's strategy for reducing CO_2 emissions from road vehicles. In the first part of the article, the development of electric cars and their functioning is described. A key component of electric cars are batteries; therefore, various types of batteries, battery charging, and types of charging stations, which occur in Slovenia, are described in this article. An extensive network of charging stations is essential for the use of electric vehicles. A map of charging stations and the number of charging stations in Slovenia are presented. Currently, the most charging stations are located in central Slovenia; this is in the area around Ljubljana. In addition, to an extensive network of charging stations, the introduction of electric vehicles also requires financial incentives to buyers of electric vehicles. Slovenian environmental public funds or Eco Fund grants provide financial incentives to buyers of electric cars. In Slovenia, there are two types of financial incentives.

Povzetek

Članek govori o električnih avtomobilih v Sloveniji. Uvajanje električnih avtomobilov je nujno za dosego ciljev strategije Evropske unije za zmanjšanje emisij CO_2 iz cestnih vozil. V prvem delu članka je opisan razvoj električnih avtomobilov in delovanje le-teh. Ključni sestavni del električnega avtomobila so baterije, zato so v članku opisani tudi različni tipi baterij, polnjenje baterij ter tipi polnilnih postaj, ki se pojavljajo v Sloveniji. Dobro razvejana mreža polnilnih postaj je nujna za uporabo električnih vozil. V članku je prikazan zemljevid in število polnilnih postaj v Sloveniji. Trenutno je največ polnilnih postaj lociranih v osrednji Sloveniji, torej v okolici Ljubljane. Poleg dobro razvejane mreže polnilnih postaj so pri uvajanju električnih vozil

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potrebne tudi finančne spodbude kupcem električnih vozil. V Sloveniji za finančne spodbude za nakup električnih vozil skrbi Slovenski okolijski javni sklad oziroma Eko sklad. V Sloveniji sta na voljo dva tipa finančnih vzpodbud.

1 INTRODUCTION

The European automotive industry is a world leader in developing clean and energy efficient technologies based on combustion engines, because it has invested heavily in research and development since the year 2000. It is also one of the key European industrial sectors, since it is competitive, innovative and supports a wide range of related industries, [1].

The European Union has set a long-term strategy to reduce CO_2 emissions from road vehicles and much has been realized already. Regulation (EC) No. 443/2009 on the setting emission performance standards for new cars requires that the target of reducing average CO_2 emissions of the new cars to 130 g/km be fully meet by 2015. The automotive industry will need to invest even more in emission abatement technologies, including intelligent traffic management technologies and further improve the efficiency of internal combustion engines, [1].

Providing long-term sustainable mobility calls for more energy-efficient vehicles that are powered by alternative energy sources. Electric vehicles offer a solution from the dependency on fossil fuels and for reducing CO_2 emissions. Electric vehicles are the first choice in transition to a more efficient traffic, [1].

2 DEVELOPMENT OF ELECTRIC VEHICLES

Electric vehicles embody our recent green-oriented mentality, but they are by no means a new innovation. They have been on the market for more than a century and have an interesting history of development, which continues. The first countries to develop an electric propulsion system were France and England. In 1835, Professor Sibrandus Stratingh drew a design of an electric car, which was later realized by his assistant Christopher Becker. In America, Thomas Davenport and Robert Davison, who made the electric vehicle more useful, contributed to the development of electric vehicles. In the following years, the development of electric vehicles went mainly towards the larger capacity of batteries for storing electricity, which was a prerequisite for a greater practicality of electric vehicles. Over the years, the highest possible speed of electric vehicles increased; in 1899, the limit of 100 km/h was broken. The speed achievement was credited to the Belgian Camille Jenatzy, whose vehicle was named ‘Never Satisfied’. Electric vehicles had, in comparison to other technologies in the industry, a number of advantages. Compared to vehicles powered by gasoline, they were quieter, did not spread any unpleasant odours in the surroundings and were not causing vibrations when functioning, [2], [3], [4].

A great advantage over petrol vehicles was also that there was no need to shift gears when driving, which was causing a lot of clumsiness in the competitive technology, [4].

The dominance of electric vehicles lasted somewhere until the beginning of the 1920s, with peak production in 1912, [3]. The reasons for the turnaround in the favour of the industry of vehicles with internal combustion engines are different. The construction of long roads between cities required a greater range of vehicles, which electric vehicles were not able to handle. In

Texas, new oil reserves were discovered, which reduced the cost of use of vehicles with internal combustion engines. The refinement of the ignition system of a petrol engine in 1912, which was presented by Charles Kettering, also had a significant impact on the turnaround. Ultimately the industry of petrol engines obtained its dominance with mass production of internal combustion cars from the Henry Ford factory, which offered vehicles to its customers that were more than half the price of electric cars, [2], [4].

Electric vehicles have been used only for specific purposes, such as vehicles for transporting milk, golf cars, and trucks. In the 1970s, the oil crisis has led to renewed interest in electric vehicles, which would alleviate the dependence of the transport sector on the situation on the oil market. The California Agency for Clean Air demanded that car manufacturers invest in the development of vehicles with low emission levels; the main objective were electric vehicles with zero emissions, [2], [5].

The biggest sales success was experienced by the EV1 model from General Motors, which represented the only car that met all the objectives of the Office for Energy of United States of America upon its arrival on the market. It was produced from 1996 to 2002 and was offered to customers through a lease agreement. As a reason for halting the production of the EV1, General Motors stated a lack of profitability. The public blamed pressure of oil lobbies and the fear of automobile companies about any strict rules regarding automotive emissions in other countries. Some of the EV1 autos are kept in various technical museums, but most were scrapped and recycled, although users of EV1 created strong publicity against these measures, [2], [5].

In 2004, the company Tesla Motors began developing an electric sports car, the Tesla Roadster, which came on the market in 2008. The Roadster was the first car with a built-in Li-ion battery. It boasts record-breaking driving performance, since it can travel 320 km on a single charge and accelerate from 0 to 100 km/h in just 4 s. [2], [5].

3 WHAT ACTUALLY IS AN ELECTRIC VEHICLE?

An electric vehicle is a vehicle that is powered solely by electricity stored in batteries located inside the vehicle. In a simple propulsion system, an accumulator powers an electric motor that enables the rotation of the wheels through mechanical transmission. This kind of a drive system reflects the simplicity of construction and good efficiency, [6]. An electric vehicle does not generate greenhouse gases. It can be powered by electricity generated from renewable energy sources; not only is the level of pollution zero, but the use of electricity generated from renewable energy sources also reduces the level of emissions, [2], [7].

Advantages of electric vehicles over conventional vehicles are lower maintenance costs, since the electric vehicle has fewer moving parts, thus allowing better utilization of energy. Electric vehicles do not need engine oil, a clutch or a transmission, and enable linear accelerations [7]. Due to the silent operation of the electric motor, it does not cause noise pollution and offers a more comfortable ride for passengers, [2].

Several types of electric vehicles are defined: battery electric vehicles, plug-in hybrids, and extended-range electric vehicles. A battery electric vehicle is a vehicle that uses only the energy stored in the batteries for propulsion. Plug-in hybrid vehicles use battery power as the main source for short distances, but at the same time, the internal combustion engine is running when the batteries are depleted. Extended-range electric vehicles use battery power as the main source for short distances, but when the battery is depleted, an internal combustion engine, which provides power to the electric motor, begins to operate, [2], [8].

Ball et al. [8] also distinguish different classes or categories of electric vehicles. In the L6e category are four-wheelers with a maximum authorized carrying capacity of 550 kg together with batteries and a maximum output of 4 kW of the drive motor. Such vehicles are especially suitable for urban driving, [9]. They are allowed to be driven by persons over the age of fifteen years, pensioners and drivers without B and B1 driving license. In the L7e category of vehicles are four-wheelers with a maximum weight of 400 kg and a maximum specified drive motor power of 15 kW. In this category, the maximum prescribed vehicle weight of 400 kg is without batteries. Electric vehicles in this category meet the definition of an urban electric car and are well suited for driving in urban areas. In the M1 category of vehicles are four-wheeled passenger vehicles that are intended for the transport of up to eight passengers, together with the operator of the vehicle, [2], [9].

4 BATTERIES AND CHARGING OF BATTERIES

There are several types of batteries, whose most important characteristics are specific power, specific energy, charging efficiency, the number of charging cycles and, of course, price, [2], [10].

Lead acid batteries have the longest history of use; consequently, they have a well-developed recycling process, [10]. This type of battery is very affordable; they have high voltage galvanic cells and are still in use today. Their drawback is their weight, fast draining and the impossibility of refilling if they are empty for too long, [2].

The advantage of NiMH batteries is fast charging. Their weaknesses are high price and rapid self-discharge. The use of Ni-MH batteries in electric vehicles was most widespread at the turn of the century when they have replaced lead acid batteries in the well-known EV1 model of General Motors [2], [11].

A significant leap forward regarding capacity was made with the introduction of Li-Ion batteries. Their advantages are a highly adaptable design, small weight in comparison with the other types of batteries, a small percentage of self-discharge and no memory effect, [11]. One disadvantage of Li-Ion batteries is that they lose their original capacity over time, [2].

At present, Li-FePO4 batteries have the best characteristics. They are based on the technology of Li-Ion batteries, but they differ in the selected cathode material. Their advantages are stability and security, because when in use there is no possibility of overcharging or short-circuit shock. Physical damage to the battery cannot cause an explosion. They provide a high number of refilling cycles, they are resistant to high temperatures and allow discharges with high currents. Li-FePO4 batteries also allow rapid charging and are half the weight of lead acid batteries, [12].

Table 1: *Characteristics of batteries, [13]*

Type	Specific energy [Wh/kg]	Energy density [Wh/l]	Specific power [W/kg]	Charging efficiency [%]	Lifetime [cycles]
Pb	35-40	70	100-150	68	300-500
Ni-MH	50-60	175	200	76	600-1000
Li-Ion	80-90	200	<1000	80	1200
Li-FePO4	110	220	<3000	90	2000

Table 1 clearly shows that Li-FePO4 batteries have the best characteristics, they exceed other types of batteries in all characteristics that are given in Table 1.

Several different ways of charging electric cars exist. Typically, electric vehicles are recharged at home through a single-phase 220 V socket. Charging takes place via a power adapter that is already installed in the vehicle. This way of charging has a power supply of 3 kW and is usually very slow. For faster charging of electric vehicles, manufacturers of charging stations have developed a power adapter, of 22 or 43 kW, which is installed in the vehicle. Charging also takes place through three-phase socket outlets with a voltage of 400 V and the use of an external charger with an AC-DC converter. The charging power is 50 kW, [2], [14].

Table 2: *Technical characteristics of charging stations, [14]*

Charging time [h]	Power supply	Voltage	Maximum current
6-8	Single phase – 3.3 kW	220 VAC	16 A
2-3	Three-phase – 10 kW	400 VAC	16 A
3-4	Single phase – 7 kW	220 VAC	32 A
1-2	Three-phase – 24 kW	400 VAC	32 A
0.3-0.5	Three-phase – 43 kW	400 VAC	63 A
0.3-0.5	Direct current – 50 kW	400-500 VDC	100—125 A

Table 2 shows that the charging process takes the longest time at a voltage of 220 V, a maximum current of 16 A and a single-phase power supply with the power of 3.3 kW, which represents a home socket outlet. The battery of an electric vehicle is recharged in the shortest time with a DC power supply with power of 50 kW, voltage of 400 to 500 V and current of 100 to 125 A. [2], [14]

5 CHARGING STATIONS

Electric vehicles need charging stations, where batteries are filled with electric energy. In most cases, the manufacturer of electric vehicles or batteries provides a suitable charger, through which energy is transferred from the energy grid to the battery. The charging of electric vehicles is similar to charging the battery in a mobile phone; the only difference is that greater electrical power is needed for charging electric vehicles. Several alternative methods for charging electric vehicles are developed, including those that obtain energy from renewable energy sources, [2], [15].

The existing infrastructure of gas stations in developed countries makes it easy to introduce an additional offer of electric charging stations. On the existing electrical installation charging stations that enable the transmission of electricity into electric vehicles could be connected. In addition to petrol stations, it is reasonable to install fast charging stations in all areas with many parking spaces. These are, for example, public parking spaces and parking spaces of hotels, airports, restaurants, shopping centres, and similar facilities, as well as parking spaces used by employees of businesses during working hours, [2], [14].

Charging stations are roughly divided into two categories, which differ according to the use of the charger. A smart charging station is connected directly to the battery, which is recognized by the charging station itself. Other charging stations represent just a source of electrical power. There are two methods of charging: traditional or conductive connection and inductive connection, [2], [15].

In the case of conductive charging, the connector provides a secure connection between the charging station and the charging connector on the vehicle. The electric vehicle is connected to the primary outlet that usually has a voltage of 220 V at home; electric current flows from the charging station through the charging adapter into the battery and thus charges the battery of the electric vehicle. The charger is usually located outside the vehicle, or it may be installed in the vehicle. In the case of inductive charging, the charger has no direct electrical connection to the vehicle, as the energy is transmitted through a magnetic field, [15]. The identification of the user is of major importance for the application of charging stations. User identification allows charging for use, prohibition of use, activation or deactivation of the device. Several different methods of identification have been developed. The charging station can identify the user via a personal identification code (PIN), through radio frequency identification (RFID), over messages sent from a mobile phone or via a key belonging to a specific individual. [2], [16]

Borzen (Slovenian power market organizer) and SODO (electricity distribution system operator) are responsible for the infrastructure of charging stations for electric vehicles in Slovenia according to the proposal of the National Energy program (NEP), [2]. The most active companies in this area are electricity distribution companies Elektro Maribor and Elektro Ljubljana. The first public charging station in Slovenia was activated on 9 April 2009 in Ljubljana, at Castle Kodeljevo, [2]. In summer 2015, the map of public charging stations in Slovenia (on the website of the company Elektro Ljubljana) lists 127 public charging stations; 58 of them are located in the vicinity of Ljubljana, and the fewest charging stations are in the northwest and southeast of Slovenia, [17].

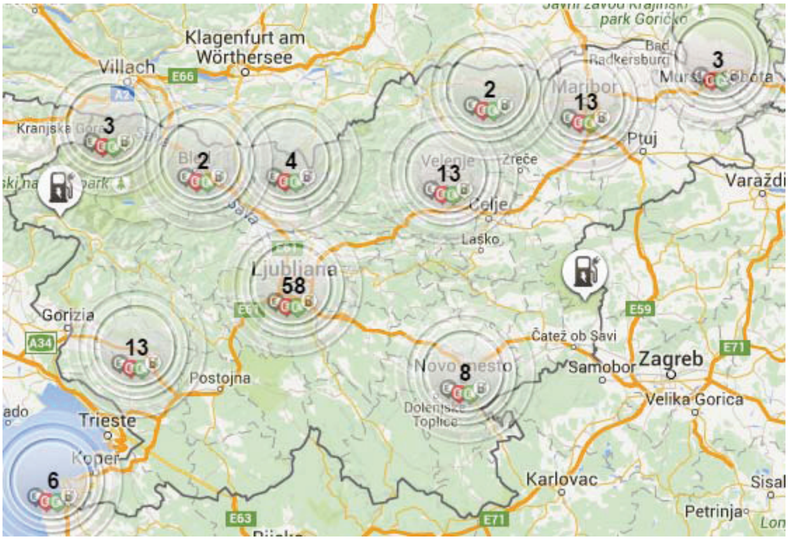

Figure 1: *Detailed map of charging stations in Slovenia (Source*: http://www.elektro-crpalke.si/, *31.8.2015)*

Slovenia's largest provider of public charging stations is Elektro Ljubljana, which enables the charging of electric cars, electric motorcycles, and bicycles with an electric motor. Various charging stations have different ways of connection. Connecting via the infrared port (IR ID), activation by using users' mobile phone (GSM) or the charging station is activated, and the vehicle merely has to be connected (Plug & Charge), [18].

In public charging stations in Slovenia six types of connectors can be found (Figure 2): normal socket, 3-pin socket, 5-pin socket, 7-pin socket, CHAdeMO DC Quick charger and Tesla Supercharger. [17]

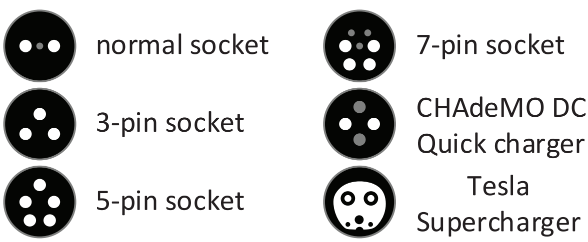

Figure 2: *Types of connectors, [17]*

Figure 3: *Etrel's charging station (Source:* http://polnjenjeev.etrel.si/grid/evcharging_we_our_solutions*, 31.8.2015)*

The charging station consists of a robust housing that resists unfavourable weather conditions, and the ergonomic design is easy to use. Charging the user for the service is ensured by using user identification and embedded counters. The charging station allows users to book a charging station, see the consumed energy and send messages to the users' mobile phone about the completion or an unexpected interruption of charging. For the users of electric vehicles, a web portal is also available. This web portal provides users with information about the occupancy of charging stations, with the ability to book a charging station and with the supervision of charging of users' electric vehicle. The portal also functions as a mobile application, through which the user searches for and books free charging stations and also supervises the recharging of his electric vehicle, [2], [19].

6 FINANCIAL INCENTIVES FOR THE PURCHASE OF ELECTRIC VEHICLES IN SLOVENIA

In Slovenia in 2015, there are currently two financial incentives for the purchase of electric vehicles.

6.1 Public tender 31SUB-EVOB15

Public tender 31SUB-EVOB15 concerns non-refundable financial incentives to individuals for purchase or investment into electric vehicles. An individual is eligible for a grant:

- in the case of purchasing a new electric vehicle,
- in the case of purchasing a new hybrid vehicle,
- in the case of purchasing a new electric vehicle with a range extender, or
- in the case of converting a vehicle with internal combustion engine into an electric vehicle, [20].

Grants may be awarded for the purchase of vehicles in categories L7e, L6e, N1 and M1 with electric propulsion without CO_2 emissions. Incentives can also be granted for the purchase of hybrid vehicles and vehicles with a range extender; however, CO_2 emissions must not exceed 50 g of CO_2 emissions per km, [20].

The total budget for the public tender is €500,000. The amount of the financial incentive is:

- €5,000 for a new or a processed electric vehicle without CO_2 emissions in the category M1;
- €3,000 for a new or a processed electric vehicle without CO_2 emissions in the category L7e;
- €3,000 for a new hybrid vehicle or an electric vehicle with a range extender with CO_2 emissions less than 50 g of CO2 emissions per km.
- €2,000 for a new or a processed electric vehicle without CO_2 emissions in the category L6e, [20].

Each natural person that has a permanent residence in Slovenia is entitled to the financial incentive, [20].

6.2 Public call for loans for environmental investments 53PO15

The subject of the public call is loans, for environmental investments, of the Eco Fund. Among the environmental investments are, [21]:

- Purchase of an electric vehicle with zero CO_2 emissions.
- Purchase of a hybrid vehicle or a vehicle with a range extender. CO_2 emissions of the mentioned vehicle types must not exceed 110 g/km, [21].

The total budget for the mentioned public tender is ten million euros. Loans are available for companies, entrepreneurs and natural persons with permanent residence in Slovenia. Loans are not available to legal entities that, [21]:

- do not have settled overdue financial obligations to the Slovenian Eco found;
- do not have settled tax or other financial obligations to the Republic of Slovenia;
- have a blocked bank account, [21].

The minimum amount of loan is €25,000, and the maximum amount is two million euros. The total debt of the borrower at the Eco Fund may not exceed ten million euros. The interest rate on the loan is EURIBOR plus a minimum of 1.5%. The repayment period is five years for the purpose of purchasing electric vehicles, [21].

7 CONCLUSION

In 2014, Slovenia had 1,412,315 registered road vehicles. Unfortunately, the Statistical Office of the Republic of Slovenia did not collect data about what powered them before 2014, and there is not yet any data for 2015. However, in 2014, around 53% of registered road vehicles were using gasoline, around 47% of registered road vehicles used diesel, and only 0.001% of all registered road vehicles were electric vehicles. In 2014, there were 153 registered electric vehicles and 86% of those were less powerful passenger cars, [22].

As already mentioned in Chapter 5, there are already 127 public charging stations in Slovenia. The network of charging stations in Slovenia is constantly expanding. Electric charging stations are and will be part of the Slovenian power grid; therefore, they represent a consumer of electrical energy. However, even in the case of a widespread use of electric vehicles and thus an extensive network of charging stations, the latter would not represent a significant load on the Slovenian network. If there were 500,000 electric cars in Slovenia and each of them would travel 20,000 km per year, with a consumption of 100 Wh/km, we would require an average power of 114 MW to charge all the electric cars. This represents only 5% of the total energy produced, [2], [15].

As said in Chapter 6, in Slovenia there are also financial incentives for the purchase of electric cars and thus long-term sustainable mobility. Electric vehicles will still cover the current target markets. A rapid increase in the use of electric vehicles is expected when battery technologies will improve. Studies show that the market for electric vehicles will comprise 1 to 2.7 % of the total market in 2020 and 11 to 30% of the total market in 2030, [1].

For hybrid cars, the expected sale is 4% in 2020 and 5 to 20% in 2030. For buyers of electric vehicles, the economic efficiency of vehicles is most important. The price of electric vehicles will have to decrease due to the progress in the electric vehicle technology and market demand. Electric vehicles have enormous potential for the solution to the challenges of the European Commission such as climate changes, independence from fossil fuels, local air quality, and the storage of renewable energy over the smart grid, [1].

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